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Performance Evaluation of Microwave Link: Comparative Case

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ABSTRACT

Purpose: To investigate the impact of climatic and environmental variations on microwave link performance, with a focus on evaluating the accuracy of rain attenuation models provided by the International Telecommunication Union (ITU) compared to real-world measurements.
Materials and Methods: This study conducts a comparative analysis between theoretically calculated rain attenuation based on ITU standards and actual measured data obtained from microwave link records of Al-Madar Company in Benghazi. The methodology relies on analyzing real operational data within a specific geographical and climatic context to assess discrepancies and performance implications.
Results: The findings reveal noticeable differences between ITU-based calculations and measured attenuation values, indicating that applying generalized international standards without local adaptation may lead to inaccuracies in microwave link budget estimations and overall system performance.
Conclusion: The study highlights the necessity of incorporating region-specific climatic data into microwave link design. It demonstrates that adjusting ITU standard values based on local measurements can significantly improve the accuracy and reliability of communication system performance predictions, making this approach valuable for future network planning and optimization.

Keywords: Link budget, ITU, Rain attenuation, RSL.

Audioabstract:

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1. INTRODUCTION

Microwave links are a cornerstone of communication systems, wireless data transmission systems, and numerous other applications. Maintaining and continuously improving microwave link performance significantly impacts the performance and quality of the communication network. This research primarily aims to establish a preliminary reference for future microwave link applications.[1] specifically within communication systems under

Conditions similar to those in Libya, through the theoretical and practical analysis of a real microwave link. Therefore, a microwave link was selected from among those operating within the Libyan communication network, specifically in Benghazi city. This link, spanning 7.44 kilometers and operating at a frequency of ,15 GHz connects between two communication towers and serves as a real-world example for system performance analysis. This analysis involves comparing standard and actual values, along with the resulting analysis findings. Figure 1 illustrates the topological location of the link according to the pathloss software used by Almadar Aljadid Company.[2]

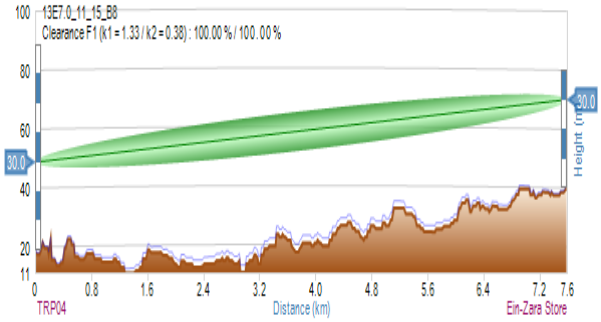

Fig. 1: Topology location of TOK1 link.

This research covers the following main objectives:

- Applying mathematical and computer models to solve problems in communications engineering.
- Theoretical formulas for signal propagation.
- Losing track and calculating the link budget.
- Calculating the fade margin.

2. METHODOLOGY

First, a general theoretical analysis of microwave communications is performed. Second, the actual microwave link was analyzed and calculations were performed to verify the expected results. Finally, the practical results were compared with the theoretical results to reach conclusions.

3. THEORETICAL ANALAYSIS

Microwave describes the contemporary current signals between 300 MHz to 300 GHz frequency ranges, microwaves have a resultant wavelength among $\lambda = \frac{c}{f}$ =1m and λ =1mm respectively.[3] These are ideal for transmission of data from point to point or to multipoint other because microwave power can infiltrate smog, rainfall, snow and clouds[3]. Microwave communication broadcast signals through radio using a progression of microwave towers. Microwave is a form of line of sight (LOS) communication, because it requires the obstruction less transmission between the receiving and transmitting towers for signals to be communicated properly at both ends, microwave communications is the most commonly used transmission technique for telecommunication services era. The choice for microwave when it comes with data communications is because of several advantages over other communication mediums (Infrared, optical fiber cables and etc).[4]

- Microwave link is possible to deploy in a day.
- Microwave radio link is flexible in the capacity that can be increase at negligible cost. Moreover, microwave radio link can be reinstalled depending on the customer requirement or if network demands changes. Therefore, losing client does not make a sense that assets are lost as in case of fifer optic.
- Microwave radio infrastructure is already available for various networks in the rooftops, celluar poles and residing towers of microwave radio transmission.
- Microwave radio systems are not inclined to common disastrous breakdown of fiber cable systems occurred by cable cuts, it may be fixed in no time rather than waiting for hours or days.[5]

On the other hands, the following problems may have to be faced:

- Seriously affected by rain fading of the link increases and there would be a possibility for total loss of the link.
- Line of sight is strictly required.
- The length of the link is limited to the frequency band used.

Basically, a typical microwave system consists of main three parts such as IDU (In Door Unit), ODU (Out Door Unit) and antenna. However, because of reflection, refraction and diffraction issues, sometimes transmitted power may not be detected sufficiently at the receiver end. There are several terminologies used for design of a specific link. Some of those are:[6]

1- Free space loss:

$$L_{fspl} = 92.4 + 20log_{10} f + 20log_{10} d \quad (1)$$

Where:

f is frequency in (Ghz) and d is distance in (km)

2- Link budget:

$$P_{RX} = P_{TX} - L_{TX} + G_{TX} - L_{PL} + G_{RX} - L_{RX} \quad (2)$$

Where:

P_{RX} – Received signal level (dBm)
P_{TX} – Transmitter output power (dBm)
L_{TX} – Transmitter losses (dB)
G_{TX} – Transmitter antenna gain (dBi)
L_{PL}– Total path loss (dB)

G_{RX} – Receiver antenna gain (dBi)
L_{RX} – Receiver losses (dB)

3- Rain attenuation:

$$A_{0.01} = A * d * r \quad (3)$$

$$A = aR^b$$

$$r = \frac{1}{1+d/d0}$$

$$d_0 = 35e^{(-0.015*R)}$$

Where:

$A_{0.01}$– rain attenuation rain attenuation at 0.01 from the time the signal unavailable

A- the specific attenuation

r - reduction factor

d_0- the rain cell

d -the path length in (km).

4- Measured rain attenuation:

$$MRA = RSL(clear\ sky) - RSL(rain\ sky) \quad (4)$$

5- Fade margin:

$$f_d = link\ budget - threshold\ level \quad (5)$$[7]

And some of the parameters that are taken into consideration when designing a microwave link, such as:

Fresnel zone

Antenna gain

Tower height

Diversity

Path unavailability

Required SNR (Signal to Noise Ratio)

Other losses connected with the system.

4. ACTUAL LINK ANALYSIS

There are assumptions made by microwave link designers for link budget calculations and path profile analysis to achieve quality coverage at a lower cost in transmission power.

In the practical analysis of the calculations, it was found that the measured attenuation differs from that calculated theoretically, and there was also a difference in the value of the fade margin, which in turn will affect the rest of the parameters that are used in designing the microwave link, such as the link budget, the level of transmitting and receiving power, which will cause large losses in communication and reduce Path reliability. On the other hand, it will increase the cost and difficulties that link designers in telecommunications companies will face. Therefore, the recalculation was performed using actual (recorded) data from Al-Madar Company regarding the basic parameters in (Table1) using the formulas given in Section III.[7]

Table 1: Calculation results of TOK1 link.

Parameter	Value				Unit
	Direction A		Direction B		
Site	TOK 1		MARJ-NEC		
Distance	7.44				km
Frequency	14963		14543		MHz
Tower coordinate (long/lat)	0204 625.5 7E	320831. 20 N	0204954.8 4E	32110 0.40 N	deg
Polarization	H		H		
TX height on tower	43.00		77.00		m
TX azimuth	47.24		227.27		deg
TX antenna	SB 3-142B (TR)		SB 3-142B(TR)		
TX power	`16		16		dBm
RX level	-67.30		-54.18		dBm
Threshold	-67.30		-67.30		dBm
Fade Margin	11.60		11.43		dB
Rain Model	P530				
Rain Model Region	Rain Region, ITU Region				
Region	D				
R 0.01(mm/h)	19				

5. RESULTS

For optimization, new values got in recalculation process and a comparison was made between the actual values and the theoretical values.

First and foremost, the measured rain attenuation (MRA) was calculated by recording receiver signal level (RSL) values during rainy sky and clear sky periodically every five minutes a day for four links Includes study link, to ensure more accuracy in the results (Table 2).

Table2: Receive level in rain and clear sky of TOK1 link.

Data date	at hour	LevelR_X (rain sky)	LevelR_X (clear sky)
15/12/2024	12:16PM	-45.1	**-39.2**
15/12/2024	12:21PM	-45.3	**-39.2**
15/12/2024	12:26PM	-44.9	**-38.8**
15/12/2024	12:31PM	-45.3	**-38.6**
15/12/2024	12:36PM	-45.7	**-39.1**
15/12/2024	12:41PM	-46.3	**-39.8**
15/12/2024	12:46PM	-46.4	**-40.2**
15/12/2024	12:51PM	-46.8	**-40.1**
15/12/2024	12:56PM	-47.4	**-39.7**
15/12/2024	01:01PM	-47.7	**-39.9**
15/12/2024	01:06PM	-48.0	**-39.9**
15/12/2024	01:11PM	-48.9	**-39.1**
15/12/2024	01:16PM	**49.2**	**-38.7**
15/12/2024	01:21PM	-48.6	**-38.5**

Then (MRA) is calculated by finding the difference between the RSL values in the two different periods. Then taken the difference between the rain attenuation calculated by ITU model as shown (Table 3) and (Fig.1). The measured rain attenuation from Al-Madar Al-Jadeed Company.

$$MRA = (-40.2) - (-49.2) = 9\ dB$$

Table 3: Summary of calculated and measured rain attenuation for four links.

Name	Freq. (MH)	Distance (km)	Attenuation (dB)	
			ITU model calculation	Links measurement
TRP10	14711	1.37	1.875	**4.210**
T5128	14543	5.58	6.591	**.78**
TOK1	14781	7.44	8.286	**9.000**
ABY2	14725	9.96	10.297	**11.695**

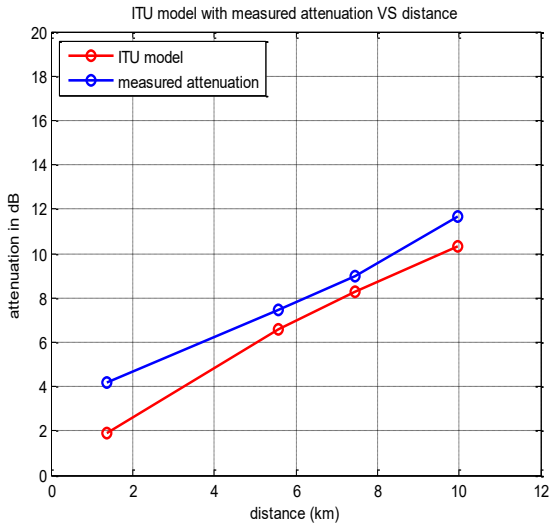

Fig. 2: Calculated and measured rain attenuation.

On the other hand, readings of the received signal level were taken in another period and the climate was moderate. It was found that the minimum reception level was (-43.9 dBm) and the maximum was (-38.2 dBm) according to the recording data that shown in (Table 4).

Table 4: Recorded receive level of site.

Data date	at hour	R_X Level	Notes
06/10/2024	11:00 AM	-38.2	MaximumR_X
06/10/2024	11:15AM	-38.1	
06/10/2024	11:30AM	-38.4	
06/10/2024	11:45AM	**-38.7**	
06/10/2024	12:00PM	-39.1	
06/10/2024	12:15PM	-39.6	
06/10/2024	12:30PM	-39.9	
07/10/2024	12:45PM	-41.2	
07/10/2024	01:00PM	-43.8	
07/10/2024	01:15PM	-43.9	
07/10/2024	01:30PM	-43.9	MinimumR_X
07/10/2024	01:45PM	-44.3	
07/10/2024	02:00PM	-43.2	
07/10/2024	02:15PM	-42.1	

Thus, $f_{d\ actual} = -43.9 - (-38.2) = 5.7\ dB$

Since the actual fade margin is in practice very less than expected values, there the new value of the threshold becomes:

$$R'_X = -67.30 - (-5.7) = -61.6\ dBm$$

Because the maximum receive level practically got is (-38.2) dBm, there is a clue that the transmit power can be further reduced as:

$$T'_X = 16 - [(-38.2) - (-61.6)] = 7.4\ dBm$$

This gives 8dBm or 9dBm reduction of used transmits power.

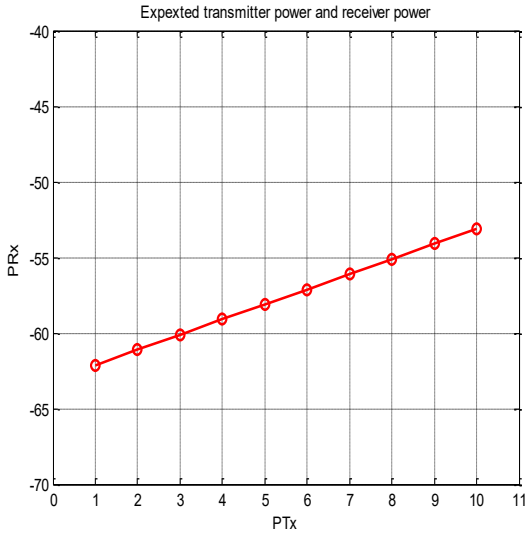

Fig. 3: Expected transmit power and receive power.

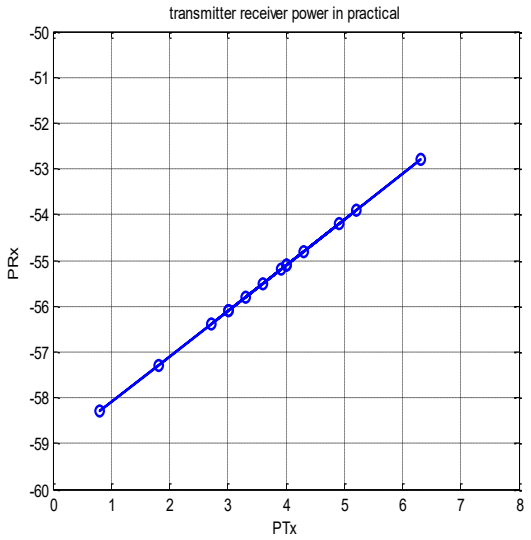

Fig. 4: Transmit and receive power in practical.

6. CONCLUSION

For microwave links optimization, analysis of theories, actual link and practical results were a combination in this research.

In design process, significant calculation errors were found that has affected path reliability, where it is that ITU region D has been considered by the contractors for Fresnel zone calculations considering rain attenuation specifically in the area though Libya belongs to ITU region N as whole. In addition, when it comes with practical data for fade margin, it proved that practically required fade margin is almost 5 dB less than the expected values gained via calculation. Moreover, sufficient receive level would have been kept lower, thus it leads to a decreased transmit power that reduces the operational cost for the license. Furthermore, figures included in section 3 could be used to find the relationships between parameter values within the given range.

This particular feasibility study concludes how theoretical aspects of microwave wireless communication vary in real environment depending on weather, climate, geography and unique challenges. And how optimization of microwave link results in more economically feasible and highly accurate performances in operation.

7. ACKNOWLEDGEMENT

This paper is a significantly extended and improved version of a previously published work presented at the 3rd Scientific International Conference in Engineering and Science. It incorporates a new case study representing a different geographical setting, along with more comprehensive real-world data, resulting in a more accurate and reliable evaluation of microwave link performance under Libyan environmental conditions. The conference paper is properly cited and clearly distinguished from the present work.

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